University of California at Berkeley
Department of Physics
Physics 7A, Spring 2019

Midterm 2
April 2, 2019

You will be given 120 minutes to work this exam. There are 4 problems worth a total of 100 points. No books are allowed, but you may use a double-sided, handwritten formula sheet no larger than an 8 ½” by 11” sheet of paper. No calculators or other electronics are allowed (wouldn’t help much anyhow…). Your description of the physics involved in a problem is worth significantly more than the final answer by itself. Show all work, be careful with signs, and take particular care to explain what you are doing. Please express your answers using the symbols provided in the problem descriptions or define any new symbols you use, tell us why you’re writing any new equations, and clearly label any drawings that you make. Write your answers directly on this exam (i.e., do not use a blue book), and do not use any extra scratch paper. Please BOX your answers. Good luck!

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DISCUSSION SECTION DATE/TIME: ________________

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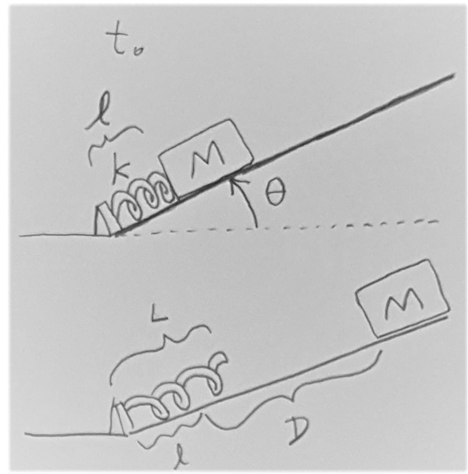
1) (25 points) Block and spring on an incline

A block of mass M is resting on an incline that makes an angle θ with the horizontal, as shown in the diagram. The block is pushed up against a coiled spring that is compressed to a length of l. The spring has spring constant k and the natural length of the spring is L. The block is initially at rest. For parts a) through d) assume that the incline is frictionless.

a) How much potential energy is stored in the coiled spring?

b) After the spring is released, how far along the incline D does the block move from its initial location before it begins to slide back down again? Express your answer in terms of M, k, θ, L, l, and any relevant physical constants.



c) How much work is done by gravity from the time the block is released until the moment the spring reaches its natural length? Express your answer in terms of M, θ, L, l, and any relevant physical constants, and take care with signs.

d) What is the impulse due to the net force on the block from the time the block is released until the moment the spring reaches its natural length? Express your answer in terms of M, k, θ, L, l, and any relevant physical constants and indicate whether it points up or down the slope.

e) If the coefficient of kinetic friction between the block and incline were μ_k, then how far up the slope D' would the block get before halting or sliding back down?

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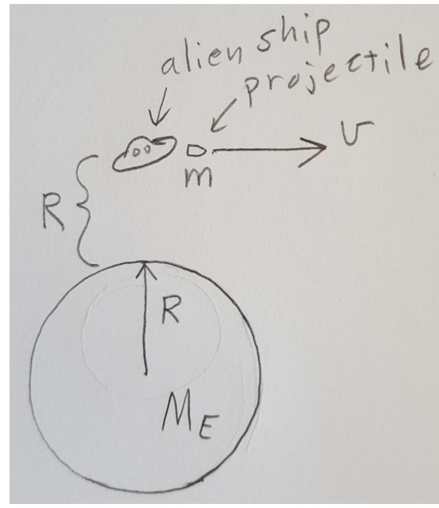
2) (25 points) Alien ship.

An alien spaceship hovers in place at a distance $2R$ from the center of the Earth, where R is the Earth's radius. The alien ship is *not* in orbit around the Earth, it is holding still and using its rockets to maintain its position.

a) The aliens shoot a projectile directly to the right in the diagram and it travels in a perfectly circular orbit around the Earth. What is the speed v of the projectile? Express your answer in terms of some combination of R, the mass of the Earth M_E, the mass of the projectile m, and any relevant physical constants.



b) What is the period of the orbit described in part a)? If you could not find the speed in part a), you may use the symbol v in your answers for this part and the rest of this problem.

c) If the aliens then shoot a projectile directly away from the Earth at the same speed as you found in part a), how far from the center of the Earth would it rise before it begins to fall back to Earth.

d) If the aliens then shoot a projectile directly to the right as in part a), but at a greater speed V so that it follows a closed orbit that reaches a maximum distance of $4R$ from the center of the Earth, then what is V?

e) Given that satellites in geosynchronous orbits travel at a distance of approximately $6R$ from the center of the Earth, how long does it take for the projectile in part d) to make one complete orbit? Express your answer in days.

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3) (25 points) Two boys on a sled

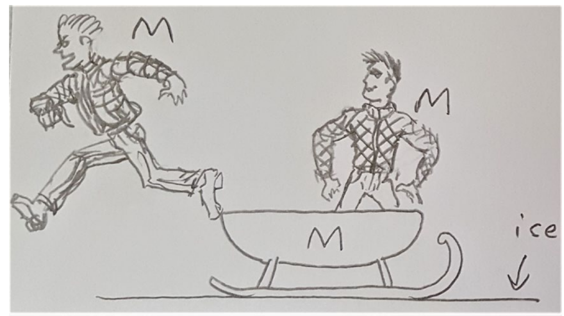
Two boys, each of mass M, are standing on a small sled that is itself the same mass M. The sled is initially stationary, and it sits on a frictionless frozen pond.

a) One of the boys jumps from one side of the sled while the other boy remains standing on the sled. If the boy jumps so that his horizontal velocity is *v with respect to the sled*, then what is the final speed of the sled?

b) If the second boy then jumps from the same side of the sled as the first boy, again with a relative horizontal velocity of v with respect to the sled, then what is the final speed of the sled?

c) If the second boy had jumped from the opposite side of the sled after the first boy jumped, then what would the final velocity of the sled be? Clearly indicate which way the sled is moving, if it is moving.

d) Now the boys attach a (massless) scoop to the front of the sled and push the sled so that it is moving with an initial velocity of V with nobody onboard. How fast is the sled moving after it has scooped up a total mass M of snow from the surface of the frozen pond?



e) Now one of the boys removes the scoop and climbs onto the sled with a mass M of snow in a bag. If he throws small snowballs of mass m_s from the back of the sled with horizontal velocity v_{sb} with respect to the sled, then how fast is the sled moving when he runs out of snow? Assume that the sled starts from rest. You may approximate the thrown snowballs as a continuous flow of matter.

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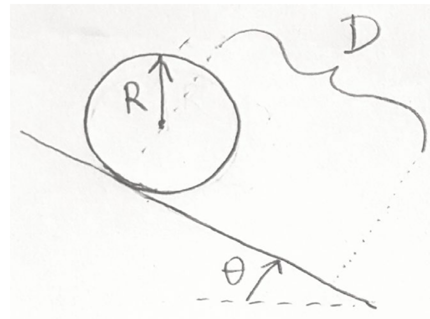
4) (25 points) Rolling cylinder

Consider a cylinder with radius *R*, mass *M*, and length L, rolling without slipping down an incline that makes an angle θ with the horizontal. Recall that the moment of inertia I_{cm} of a cylinder about its axis of symmetry is given by $\frac{1}{2}MR^2$.

a) Draw a free body diagram of the cylinder showing where each force acts on it.

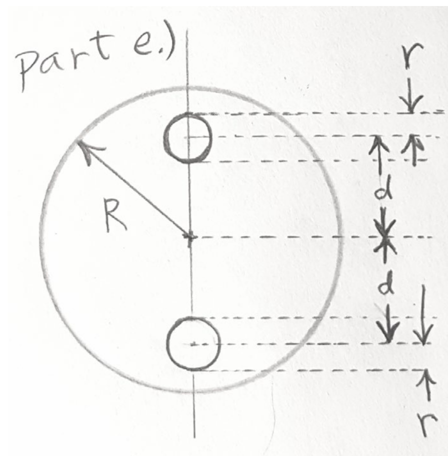


b) What is the angular acceleration α of the cylinder? Clearly indicate whether it is in the *clockwise* or *counterclockwise* direction as viewed in the diagram. Express your answer as some combination of θ, R, M and any relevant physical constants.

c) What is the minimum value for the coefficient of static friction, μ_s, required for the wheel not to slip as it rolls down the incline? Express your answer as a function of θ.

d) What is the final speed of the center of mass of the cylinder after it has rolled a distance D down the ramp? Assume the cylinder starts from rest and express your answer as a function of θ, R, M, D, and any relevant physical constants.

e) The cylinder is made of a material with uniform mass/volume density of ρ. Now two holes are drilled along the length of the cylinder parallel to the axis of symmetry. Each hole has radius r and is located with its center a distance d from the axis of symmetry of the cylinder. What is the moment of inertia of the modified cylinder about its axis of symmetry? Express your answer in terms of ρ, r, R, d, and L.



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